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Water Quality Management and Irrigated Agriculture: Potential Conflicts in the Colorado River Basin

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Introduction

The enforcement of the Federal Water Pollution Control Act Amendment of 1972 (PL92-500) has been primarily directed at "point sources" of pollution, that is, those polluters whose effluent is easily isolated and identified such as municipalities and industrial plants. Violators have been fined varying amounts depending upon the frequency, extent and type of violation. The long run goal of the legislation is, however, to eliminate all man-caused effluent--to reach a zero discharge level of effluents for all activities. If and when these standards are applied to irrigated agriculture several problems may appear, both in the attempt to enforce effluent standards and in the effect that enforcement may have on agriculture in general and irrigated agriculture in particular. Some of these problems will be suggested in a general context; a detailed discussion of some of the possible impacts of water quality controls in the Colorado River Basin will then be undertaken, with particular references to the zero discharge requirement.

General Problems

One overriding question which has not been addressed by PL92-500 or similar legislation is whether or not water quality standards are desirable on any basis other than emotional. It is clear that for many activities and cases, the social optimum will include some level of pollution. Elimination of all externalities will undoubtedly result in lower production and higher prices for all these activities than would occur at a social optimum. (Kneese and Schutlze).[1]

There is doubt about the applicability of the standards to diffuse sources. The permit criteria specifies point sources only. The act as passed required that if a point source (i.e., canal outflow, ditch, etc.) can be defined, or if the return flow is from more than 3,000 contiguous acres, the permit requirement applies. The latter portion of the act was voided in 1975, however, so that the permit requirement applies only to the point source criterion. Most irrigated agriculture involves diffuse sources of pollution, in that no one polluter's effluent can be distinguished from other polluters. There are only a few enforcement options available: to monitor each farms outflow of irrigation water, to require each farm to treat outflow or to require the water distributing agency to monitor or treat outflows. These enforcement options for the most part ignore potential pollution of ground water reserviors, and in some cases it is these âquifers which significantly effect water quality in downstream surface water, as the aquifer is drained by natural springs or seeps. Further, all of the options for enforcement will be expensive to the enforcing agency, to the polluter, and in the long run to the consumer.

There are some provisions in PL92-500 which may also affect changes in the structure of American agriculture. If diffuse sources fall under the act, the costs of meeting effluent standards appear to be a particularly large burden for smaller farms. The incentives exist to force small farms to either sell, to consolidated farms, or to reduce the size of the farms below the size to which pollution controls apply. The "family farm" may well become a garden plot for part-time farming operators.

Beyond the enforcement problem, the crucial issues about the application of water quality controls to agriculture are those of the economic efficiency and equity of imposing the standards on the agricultural sector. Will the additional costs to agriculture and consumers of agricultural products be less than the benefits generated by cleaner water? Will those who benefit be able to compensate those who lose? It is likely that the efficiency questions can only be answered within the context of a specific river basin. On the other hand, by examining a river basin, some generalities with respect to efficiency and equity may be revealed. The Colorado River Basin is the basin chosen for analysis.

PL 92-500 and the Colorado River Basin

A full description of the institutional setting in the Basin is uncalled for. However, some of the institutions which play important role in the use of the River may be affected by pollution controls. In general, Western water rights are based on the appropriation doctrine: that is, first in time, first in right. Each state contols its allocation of water among users, subject to interstate constraints. Most states allocate water rights to those uses termed "beneficial" by the allocating agency. These water rights may or may not be appurtenant to the land, and may be transferred more or less freely, depending on the state regulations.

Description of the Region

The Colorado River Basin is large and physically, economically and institutionally complex. The River has its headwaters in Wyoming, Colorado and Eastern Utah, and signigicant other feeder rivers from New Mexico, Southern Utah and Arizona. The agriculture in the region varies considerably.

Irrigated crops in the Upper Basin States (Utah, Wyoming, Colorado, and New Mexico) are generally limited to alfalfa, wheat and other small grains, and silage corn. Some fruit is grown, as are sugar beets, in a few areas. The Lower Basin states have longer growing seasons, and many cash crops are included in the rotation. Citrus crops, lettuce, tomatoes, and a variety of other high-value crops are cultivated both in the Salt River Basin of Arizona and the Imperial Valley regions. Estimations of the value of the marginal product of diverted water in irrigated agriculture range from a maximum of about $35, and an average of about $10, for the upper Basin States (Anderson, et.al.), to $70 to $75 maximum, and about $30-$35 average for the Lower Basin States (Kelso, et.al.; Hedges and Moore). Other estimates from earlier studies show somewhat less difference in value.

Two regional organizations, the Upper and Lower Colorado River Commissions, have some jurisdictional power, as do the seven states served by the river and its tributaries (including California and Nevada). The water allocation between the states is governed by two levels of compacts. The Colorado River Compact divides the water between the Upper and Lower Basins, and stipulates a given amount of outflow (7,500,000 acre feet) at Lees Ferry, Arizona. The division of water rights among states is governed by another compact for the Upper Basin states, and has been a matter of judicial decision and agreements between the Lower Basin states. In addition, water has been allocated to Mexico by treaty. Thus, the water in the Basin is totally allocated in an "average" year. Further, the agreements and adjudications which were made were based on a series of greater-than-average flow years, so that water has been over-allocated for the past years of lower flow. The institutional framework, as will be shown, may impose constraints which conflict with the water quality standards, particularly the zero-discharge requirements.

While many pollutants may be found in the effluent of users of the river, salt content is the main pollution problem. This discussion will focus on the salinity problem and while high salinity may be somewhat unique to the rivers of arid West, many of the potential conflicts between agricultural production and water quality standards for salinity are relatively broadly applicable.

The salinity problem does have one important aspect which may be typical of all river basins which have irrigated agriculture - water quality conflicts. Much of the salinity in the Colorado River is a result of natural sources rather than of man's activities. Some disagreement exists among researchers with respect to the amount of salt contributed by the natural sources; a few researchers estimate the natural loading to be from thirty to forty percent of the total salt content, while others estimate as high as seventy-five percent of the salt is contributed by natural sources. Estimates made by Utah State University (1975) researchers indicate 26%, or 702,300 tons of salt out of 2,676,000 total tons, are contributed by irrigated agriculture in the Green River Sub-basin; for the Upper Main Stream of the Colorado, 1,374,760 tons or 27% of the 5,012,000 tons were from agriculture; for the San Juan Sub-basin, 232,000 tons or 23% of the 1,010,000 tons were from agriculture; for the Lower Main Stream, 273,500 tons or 31% of the 882,260 tons were from agriculture; and for the Little Colorado River Sub-basin, 18,550 tons or 16% of the 116,300 tons were from agriculture. Clearly, a major portion of the salinity problem cannot be attributed to irrigated agriculture.

The Effect of Water Quality Standards

Given the physical and institutional settings of the Colorado River Basin, what can be expected if water quality standards are imposed on irrigated agriculture?

The first, and possibly the most critical, problem will be the enforcement of the standards in general, and the zero discharge requirement in particular. Quantifying pollutants from each point source will require a monitor for every farm, if not by the enforcement agency then by the water distributing agency whose discharge in turn is monitored, in order that the cost of treatment (or fines) can be adjudicated. Monitoring groundwater return flows, which add considerable salt to downstream flows, would be economically infeasible if not physically impossible.

Second, if meeting the standards is expensive, particularly if the cost of monitoring is born by farmers, than any loopholes which would allow escape from the standards will likely be implemented. For example, if irrigation canal return flows from a farm can be considered a point source, the farmer will likely adjust his irrigation practice to avoid the effluent point or conveyance. Natural seepage or water spreading practices may replace concrete ditches returning water to larger irrigation canals. If fines are very heavy, as the law states ($5,000 for the first offense and up to $50,000 per repeated offenses), it seems likely that ponding or water spreading would be a cheaper alternative to a monitorable point source. Adding to the return flows to groundwater may, in fact, increase the salt load, depending on the salt content of underlying strata. In much of the Upper Colorado Basin, impervious, salt-laden shale strata cause groundwater flows to pick up heavy salt loads, which often augment downstream surface water through springs and seepage. Thus, water quality controls may lead to a worsening of stream quality in lower reaches.

If the standards are imposed on canal companies, as seems more probable given the magnitude of effort required to monitor each farm, then it appears likely that canal companies will be forced to construct end-of-pipe treatment plants. These plants will be quite complex, since pesticides and fertilizers will have to be removed along with the salt load. Current treatment costs for muncipal effluent (BOD, colifirm, etc.) average between $25 and $50 per acre foot.[2] The estimated cost of a desalinization plant is about $33 per ton of salt removed, (Kleinman, et.al.) of an average of about $80-85 per acre of irrigated cropland, for the Colorado River Basin. For municipal treatment facilities, as plant size decreases unit treatment costs rise. If decreasing costs to scale also hold for desalinization a small irrigation company would likely have extremely high treatment costs. Given current values of irrigation water in both the Basins, a significant burden would be placed on agriculturists. The construction and operation of treatment plants will likely have to be publically financed, with a pay-back procedure similar to the construction of irrigation dams and canal systems. Further, the fees levied on water users would likely be based on water diversions, rather than on effluent levels, because of the high cost of monitoring each farm in a system and because individual farms might avoid the effluent charge by the ponding or spreading techniques discussed aobve. This system of charges could be both economically inefficient and inequitable. In fact, such a distribution of charges could lead to encouragement of pollutant production (particularly fertilizers and pesticides), given the common property aspect of the treatment plant ownership.

There are some on farm technological adjustments which can be made to reduce the pollutant levels of surface water. First, farmers can change their irrigation system to sprinkling. Second, farmers can develop a total containment approach, similar to the measures planned by the steam-powered electrical generation and mining companies. The shift to sprinkling irrigation can reduce salt loading by a substantial amount, depending on rates of application and crop rotations (Hanks, et. al.). Several problems arise with sprinkling irrigation, however. Although salt outflow may be decreased, it is not eliminated by sprinkling.

There is a build-up of salt in the root zone with sprinkling, unless sufficient water is used to "flush" the salt out or unless tile drains are used to prevent capillary effects from bringing salt to the root zones. Even tile drains will not prevent salt building where irrigation water is already salt-laden. Clearly, flushing would violate water quality standards and zero-discharge almost by definition. If the surface is tile-drained, the additions of salt to groundwater, and thence to surface flows, may be eliminated and the surface effluent managed. However, the imposition of zero discharge could eliminate the use of the drains even in the areas which have adopted the practice, since these drains can be identified as point sources. Without flushing or tile drains, yields and profits will decline substantially over time. This reduction in profitability has a compounding effect. Most studies show that in order that sprinkler irrigation be as profitable as flood irrigation, rotation must change to include more intensive, higher valued crops (Meale;

Cannon). Otherwise sprinkling yields either low or no profit, since the capital requirement is very high. Many of these high-valued crops in the Upper and Lower Basins are salt sensitive. Thus, if water quality constraints eliminate flood irrigation and force sprinkling with or without tile drains, irrigated agriculture will have a limited role in at least the Upper Colorado Basin in the long run. The extent to which irrigation will continue in the Lower Basin is uncertain, simply because of the higher valued crops. It is doubtful that marginal land could sustain the added costs of sprinkling, tile draining, or water treatment.

The alternative to sprinkling is total containment. Ponding for evaporation would be relatively inexpensive. Some have suggested that reuse of ponded water would reduce the effluent problem as well. Unfortunately, at least in large parts of the Basin, ponded water would be salty enough to inhibit production. In fact, many of the potential industrial users indicate that reuse of Colorado River water for cooling is questionable due to its high salt content.

The constraint on total containment by articulturalists is neither economic nor technical. The institutional framework may prevent the practice for current levels of irrigation. The Colorado River Compact establishes the outflow required from the Upper Basin; similarily, the Mexican Treaty establishes outflow for the Lower Basin. If farmers pond water, there will be a reduction of flow in the River, since current consumptive use is about 50 to 60 percent of diversions in most areas of the Upper Basin. The return flows from agriculture would be reduced by about half in the Upper Basin, and probably the same percentage in the Lower Basin. Total containment could not be accomplished without some transfer of water rights, even within each state. Several of the states have either state laws or judicial decisions which require maintenance of downstream flows (return flows). There is obviously a "taking" of water rights involved with containment, although market compensation might be the method by which total containment could be practiced by a reduced number of irrigators. Even with total containment, water quality could decline in the Colorado River, due to reduced dilution. Where high quality groundwater is used for irrigation, those flows would not augment the River. In fact, the likelihood of developing groundwater for new irrigation will be significantly reduced due to the zero discharge limitations. Those areas which have been developed, or are planned, using saline groundwater for irrigation would very likely have to be abandoned.

The total containment problem points but another weakness of PL92-500 in situations similar to the Colorado River Basin. Water quality is a function of both pollutant loading and of dilution by additions of relatively clean water. The reduction of high quality return flows in areas where high levels of natural loading occurs may well cause a degradation of stream quality. Thus imposition of rigid standards like zero-discharge could reduce the quality of the Colorado as a result of wide-scale adoption of total containment by irrigators. At the very least, it is not certain that such standards will improve water quality.

There are other technological controls which have been suggested. Canal lining and selective retirement of irrigated land have been discussed. These two approaches will have some moderating effect of salt loading in the Colorado River, but only a small portion of the salt loading could be reduced. (Utah State University) In addition, canal lining would probably cause significantly more water to require treatment since seepage does reduce the amount of surface flows which can be identified as point sources. The incentive might be to not line canals in order to avoid the treatment costs.

From the foregoing discussion, it seems possible that the implementation of water quality standards, especially zero discharge, in the Colorado River Basin will have a large detrimental effect on irrigated agriculture in both Lower and Upper Basins. In addition, the incentive to avoid the standards could lead to decreased water quality. The fundamental economic question is if benefits are gained, are these benefits, if any, greater than the implementation costs, and, further, do those who benefit compensate those who lose?

Benefits and Costs

A general theoretical treatment of the externalities of pollution leads to the conclusion that unless the pollutant is extremely harmful in very small concentrations, the social optimum will occur at a point where some externality exists (for example, Buchanan and Stubblebine). The zero-discharge requirement is too restrictive, but the intermediate standards - Best Practical Technology and Best Available Technology - may also be too restrictive with respect to a social optimum. Figure 1 illustrates the economically efficient reductions in agricultural loading, where the marginal damage avoided just equals the marginal cost of control, at R^*. (Gardner and Stewart). For the Colorado River Basin, upstream salt loading has been the cause of downstream cost to municipal, industrial, and agricultural water users.

There have been several estimates of the reduction of downstream damages, given reduced levels of salainity at Imperial Dam. These estimates range from about \$50,000 per year per/milligram per liter (mg/l) (EPA) to \$250,000 mg/l per year (Kleinman, et.al; Valentine). The costs of reducing the salt loading vary substantially. Some methods appear economically reasonable, some do not. The cost of conversion of agriculture in the Basin to sprinkler irrigation are estimated at between 1 and 4 million dollars per year per diminution of one mg/l (Utah State University). Clearly, a large cost must be born by upstream irrigators compared to a relatively small benefit. Note further that these values are averages; it is likely that some conversions to sprinkling might generate benefits equal to costs at the margin, but total conversion would pass the point of equal marginal cost and benefits, since marginal benefit would be expected to be falling or constant while marginal cost would be expected to be rising. Other methods, such as canal lining and irrigation retirement plans, have average costs approximately equal to the average benefit. These programs would not reduce the salinity by a great deal (perhaps 10%), yet these appear to be the economically feasible projects. Thus, the existence of externality costs at the social optimum is probable; however, the optimal level of upstream treatment is currently unknown. The same kinds of arguments may well apply to outflows to Mexico for the Lower Basin. Where the social optimum lies is subject for further empirical research, but it is almost assured that the social optimum in this case does not occur at zero discharge.

It has been that in at least one small Colorado River sub-basin, the Virgin River Basin, significant reduction in salt loading requires a substantial diminution in irrigated agricultural acreage. This sub-basin is relatively typical, with saline springs and erodable soils which contain moderate to high salt concentrations. In fact, the Virgin Sub-basin has less salt in the soil that the Mancos shale soils of the Cisco, Utah, region. Results of an interfaced hydro-salinity and linear programming model indicate that in order to achieve a less than 10 percent reduction in salt loading for the sub-basin, an almost 50 percent reduction in irrigated agriculture is necessary (Keith, et.al.) Foregone net returns to irrigated agriculture amount to a minimum of $1,000,000 to reduce the salt concentration by not more than 2 mg/l at Imperial Dam. One implication which may be derived is that the social optimum probably would occur at a considerably less stringent controls than zero discharge.

Some Future Consideration

The Upper Colorado Basin contains energy resources which are currently being exploited or whose exploitation is being planned. While energy is not the subject of this paper, there may well be a significant impact on irrigated agriculture as energy developes and responds to water quality standards. First, the energy developments - including steam-powered electrical generation plants, oil shale development, coal mining, and synthetic fuel plants - will all be point sources; therefore, each will be subject to monitoring and the current permit system. Because of the high cost of treating water high in salt, current plans include total containment of waste water from both processing and cooling activities. Since all the water in the Upper Basin has been allocated, these energy developments will be forced to acquire water from current holders of water rights, either by reassignment by the appropriate authorities or by purchase. Given the constraints on return flows, these energy producers will have to obtain diversion rights sufficiently in excess of their consumptive use that remaining downstream users have sufficient water available. Thus, less irrigated agriculture will exist than would be the case under less stringent water quality standards. In fact, the Colorado River Assessment Study (Utah State University) indicated that with the development of energy resources, less loading will occur as irrigation is reduced, but concentrations will rise as a result of increased consumptive use of water in the total containment activity.

There are also some side issues with respect to municipal waste treatment, both for current residents and future populations of the Basin. There is considerable evidence that effluent from many municipalities is undetectable a short distance downstream from their discharge points. The existing regulation will require large investment in sewage treatment plants by those municipalities. This burden will fall more heavily on smaller communities which generate relatively less effluent than larger metropolitan areas. The water quality standards approach ignores both the substantial costs and the practically non-existant benefits of pollution control for these municipalities.

There are also several planned water exports in the Upper and Lower Basin. While these exports are not identified as point sources of pollution, they may well have significant impacts on the water quality in the river. As water is withdrawn from the river, less dilution of the salt load takes place, and the concentration rises. These exports may be more significant to water quality than loading from either the agricultural or energy sectors, yet PL92-500 will have no regulating affect.

Summary and Conclusions

The application of water quality standards to irrigated agriculture will be, at best, difficult. Whether the law even applies to most irrigated agriculture is open to question. The ability to identify the sources of effluents, or to monitor identified sources, is doubtful. If the standards are applied, agriculturalists will have to alter their current practices and may be forced to cease irrigation due to economic infeasibility of meeting standards, particularly the zero discharge requirements. In addition, the benefits gained to downstream users will likely be much smaller than the costs born by upstream users in order to achieve zero discharge. Irrigated agriculture will not be the only sector which is affected; the imposition of the rather arbitrary standards including eventual zero discharge requirements, will impose very high costs on small rural municipalities in the Basin, with little or no detectable improvement in water quality in the river. With the advent of energy development and large water transfers, the effluent standards may, in fact worsen the water quality.

It seems apparent that PL92-500 is an ill-conceived approach to the water quality problems which result from irrigated agriculture. Given the importance of irrigated agriculture to the west, the "legalistic" physical standards approach may lead to a loss in social welfare, rather than a gain.

FOOTNOTES

1. Kneese and Schultze treat the zero discharge portion of the bill as a relatively improbable goal. Recent passage of the Clean Air Act Amendment appears to indicate that the "zero-discharge" mentality maintains a considerable influence over legislation.

2. Current sewage treatment plants are not capable of removing these pollutants.

3. Consumptive use may be as low as 30 to 40 percent in some parts of the Upper Basin.

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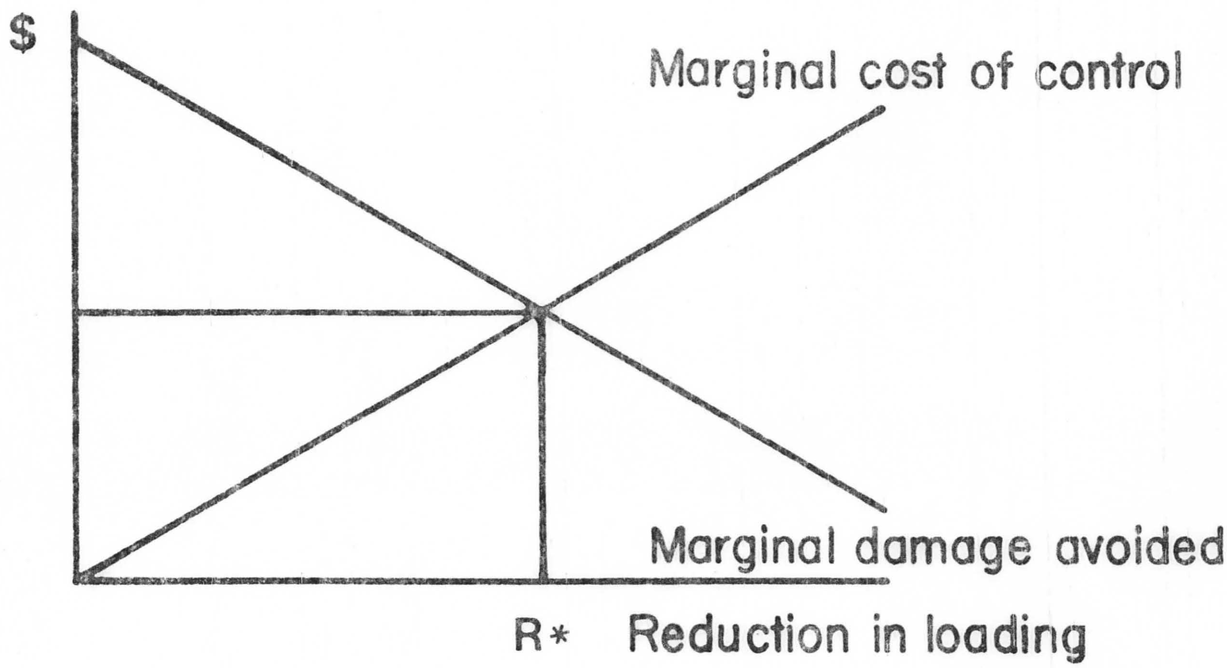

Figure 1. Optimum level of loading reduction